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CONTENTS

Effect of Storage Temperature and Size on French Fry Quality, Shrinkage and Specific Gravity of Maine Potatoes—*G. L. Terman, Michael Goven and C. E. Cunningham* 417

Acid Hydrolysis of Potatoes under Pressure—*A. S. Hunter and E. A. Talley* 425

The Utilization of Phosphorus by Two Potato Varieties on Long Island—*Walter C. Jacob and L. A. Dean* 439

The Effect of a Mild Strain of Latent Mosaic Virus X on Yield of Some of the New Potato Varieties in Maine—*P. M. Lombard* 445

Announcements ..... Inside Front Cover

Earle Volcart Hardenburg 449

Index Volume 27 Nos. 1-12 450

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Announcements

INDEX PUBLISHED

A complete index of authors and subjects of the first 26 volumes of the "American Potato Journal" has just been printed and copies are available at $3.00 each from John C. Campbell, Treasurer, Rutgers University, College of Agriculture, New Brunswick, New Jersey. This index consisting of 89 pages represents many months of work and we believe it will be of great value to libraries and members. It is bound in the same heavy blue cover that is used on the Journal. The quantity is limited so order YOURS to-day.

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Effective immediately! The annual dues in the Potato Association of America and subscriptions to the "American Potato Journal" have been increased from two dollars ($2.00) to four dollars ($4.00). This change was made after serious consideration by the members who attended the business session of the annual meeting in Memphis, December 1-3, 1950. This increase is considered necessary to meet the greatly increased cost of printing the "American Potato Journal".

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EFFECT OF STORAGE TEMPERATURE AND SIZE ON FRENCH FRY QUALITY, SHRINKAGE AND SPECIFIC GRAVITY OF MAINE POTATOES

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(Accepted for publication July 22, 1950)

Because of the usual low storage temperatures of approximately 34° to 45° at which the late potato crop is held, together with other factors, the use of Maine potatoes for processed foods, such as frozen French fries and potato chips, has been rather limited. Storage temperatures appreciably below 50°F. have been found by many investigators to result in conversion of a portion of the starch in the tubers to sugars. These sugars result in a dark brown color and "burnt" taste in the fried product, which increase with higher contents of sugars.

The present investigation was undertaken to obtain more information on the effect of storage temperatures and size on French fry quality of some of the more common potato varieties grown in Maine. A representa-

[1] Agronomist, Field Assistant, and Assistant Agronomist, respectively.

The French frying tests were made by Harold McGowan at the Caribou, Maine, plant of the Birds Eye-Snider Division, General Foods Corporation.

tive of one processing company has estimated that as much as 12,000 carloads of Maine potatoes might be used for potato chips, French fries, and similar food products if proper quality and flow of potatoes to processors can be maintained. This emphasizes the importance of such quality studies.

Procedure

Potato tubers of five varieties grown under similar conditions were sized and 50 to 60-pound samples of each size class placed in experimental storage bins in early November, 1949. Controlled temperatures of 36°, 40°, and 50°F. were used for each size class of 1½-2, 2-2½, 2½-2⅞, and 2⅞-3¼ inches for most varieties. Specific gravity was determined on 10 to 30 tuber samples, depending on size, by the air-water method. The weight of the bulk samples and of sub-samples for specific gravity were made on November 7, December 8, January 7, February 2, March 6, and April 3.

In January samples of the Katahdin variety stored at 36° and 40° were changed to 50°, 60°, and 70°, and those stored at 50° to 60° and 70°. In February and March 10 tubers from each lot were removed and tested for French frying quality. Similar samples from the continuous 36°, 40°, and 50° storage were also tested in April, as well as tubers from vines sprayed with 2,4,5-T (2,4,5-trichlorophenoxyacetate) in August. No actual determinations of sugars were made. Weights of the storage samples were adjusted for the samples removed for testing, so that shrinkage loss could be calculated for the entire storage period.

All varieties stored—Green Mountain, Mohawk, Kennebec, Katahdin, and Teton, in order of decreasing specifc gravity—were found by Wright and Whiteman (4) to remain free from sprouts at 50°F. when stored for 14 weeks or longer.

Effect on Quality

The effects of 36°, 40°, and 50° continuous temperature storage on French fry quality are shown in table 1. In general, all the lots stored at 36° or 40° produced French fries which were too high in sugar and dark in color for satisfactory quality. (In this discussion, if more than 50 per cent of the tubers fell in color grade 4, medium color and sugar, or in lighter color grades, they were considered to be of satisfactory quality for French fries in regard to color.)

At the 50° storage temperature, only at the February 3 date was a large proportion of the Green Mountain tubers of satisfactory quality. This may indicate that this variety is satisfactory during the early part of the normal storage period if stored at 50° or above. The Mohawk was also of

TABLE 1.—*Effect of size, temperature and length of storage on the color ratings of tubers of five potato varieties for French fries*

Variety	Size	Temp. (F)	Tubers Falling into French Fry Color Ratings—Per cent[1]											
			February 3				March 8				April 4			
			1	2	3	4	1	2	3	4	1	2	3	4
Green Mountain:	2-2½	36°	100	....	....	....	100	....	....	....	100	....	....	....
	"	40°	100	....	....	....	....	100	....	....	....	100	....	....
	2⅞-3¼	50°	....	....	100	....	....	....	100	....	....	....	100	....
	"	36°	90	10	....	....	100	....	....	....	100	....	....	....
	"	40°	100	....	....	....	....	100	....	....	....	100	....	....
	"	50°	....	....	....	100	....	20	70	10	....	80	20	....
Mohawk:	2½-3	36°	90	10	....	....	100	....	....	....	80	20	....	....
	"	40°	50	40	10	....	....	80	20	....	20	20	60	....
	"	50°	....	....	70	30	....	....	70	30	....	30	40	30
Kennebec:	2-2⅝	36°	10	90	....	....	100	....	....	....	....	100	....	....
	"	40°	....	30	40	30	....	....	100	....	....	....	60	40
	"	50°	....	....	....	100	....	....	10	90	....	....	10	90
	3-3½	36°	....	70	30	....	100	....	....	....	....	100	....	....
	"	40°	....	100	....	....	....	30	70	....	....	....	100	....
	"	50°	....	....	10	90	....	....	....	100	....	....	....	100
Katahdin:	2-2⅝	36°	....	....	100	....	100	....	....	....	80	20	....	....
	"	40°	....	....	100	....	....	....	100	....	....	100	....	....
	"	50°	....	....	....	100	....	....	40	60	....	....	70	30
	2⅞-3¼	36°	....	....	100	....	100	....	....	....	100	....	....	....
	"	40°	....	....	100	....	....	....	100	....	....	100	....	....
	"	50°	....	....	....	100	....	....	40	60	....	....	50	50
Teton:	2½-3	36°	....	100	....	....	100	....	....	....	90	10	....	....
	"	40°	100	....	....	....	....	80	20	....	....	100	....	....
	"	50°	....	....	....	100	....	....	40	60	....	....	100	....

[1] French frying tests were made at the Caribou, Me. plant of the Birds Eye-Snider Division of General Foods Corporation. Color standards used at the plant were as follows: (1) dark color, very high sugar; (2) high; (3) medium high; (4) medium color and sugar; (5) medium low; (6) low; and (7) light, very low sugar. Medium to medium low color and sugar are desired.

generally unsatisfactory quality at 50°. Both varieties are higher in specific gravity and total solids than other common Maine varieties. The above results are in general agreement with commercial practice, since varieties lower in specific gravity are generally used for food products. On the other hand, if sugar content and other quality conditions are satisfactory, potatoes of high specific gravity are preferred because of less fat absorption in frying and greater weight of processed food per hundred-weight of raw tubers.

The Kennebec variety, when stored at 50°, was generally satisfactory for French fries at all dates of testing. The Katahdin and Teton varieties were of satisfactory color quality on February 3, but were of poorer quality than Kennebec on March 8 and April 4. In general there was no consistent

difference between size classes of 2-2½ and 2⅞-3¼ inches regarding quality.

In regard to texture, the French fry samples were classified into three groups: mealy, intermediate, and soggy, or waxy. The Green Mountain, Mohawk, and Kennebec tubers were rated most mealy, although there were no outstanding differences for variety, size, or storage temperature. Considering all lots, the French fries were most mealy on March 8, less so on February 3 and least mealy on April 4. This, however, may possibly be due to lack of proper control between dates of testing.

The effect of shifting Katahdin tubers from low to higher storage temperatures is shown in table 2. Changing the tubers to 70° for 20 days reduced the sugar content and color of French fries markedly. This length of time of reconditioning was as satisfactory as the longer period of 38 days. At 70° all lots of tubers from 36°, 40°, or 50° storage reconditioned satisfactorily for French fries. The 60° temperature was almost as effective as 70°, although the fries from tubers changed to the higher temperature, were slightly more mealy after 20 days. After 38 days there was little difference in regard to mealiness. These periods of reconditioning are considerably less than have been reported as necessary by Alexander, *et al.* (1) for Katahdin potatoes grown in Maine.

Katahdin tubers from plants sprayed with 2,4,5-T in late August were definitely lower in French fry quality than tubers from untreated plants. This was shown by both the darker color and much less mealy texture of the fries from 2,4,5-T treatments, as compared with untreated potatoes.

Effect on Shrinkage and Specific Gravity

As indicated in tables 3 and 4, shrinkage and specific gravity increased with time in storage. Since no sprouts were removed, the shrinkage data represent the actual loss of water through evaporation and loss of solids through respiration. The increase in specific gravity represents an increase in percentage of solids in the tubers. The increase in specific gravity from December 8 to April 3 thus indicates that water was lost through the evaporation at a greater rate than solids through respiration. Treadway, *et al.* (3), however, found that at 34° to 60° storage, carbohydrate material and water were lost at nearly the same rate, so that the percentage of solids remained nearly at the original level.

Shrinkage of all lots of potatoes also increased with temperature of storage. Since specific gravity did not increase on the average with temperature, this indicates that the greater shrinkage losses at the higher temperatures were the result of higher rates of respiration and losses of solids. Water loss apparently did not increase with temperature.

Only incipient sprouts had formed at the 36° and 40° temperatures by

TABLE 2.—*Effect of shifting Katahdin potatoes to higher temperatures on color ratings of tubers for French fries*

Storage Temperature (F) Prior to Shifting	Temperature (F) to Which Shifted	Tubers Falling into French Fry Color Ratings—Per cent[1]														
		Feb. 24—20 Days					Mar. 14—38 Days					Apr. 17—21 Days				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
36°	Left at 36°	100	....	....	....	....	100	....	....	....	....	....	....	....	....	....
"	50°	....	....	....	100	....	....	100	....	....	....	....	....	....	....	....
"	60°	....	....	....	100	....	....	....	10	90	....	....	....	....	....	....
"	70°	....	....	....	....	100	....	....	....	100	....	....	....	....	....	....
40°	Left at 40°	....	100	....	....	....	....	100	....	....	....	....	....	....	....	....
"	50°	....	100	....	....	....	....	....	100	....	....	....	....	....	....	....
"	60°	....	....	40	60	....	....	....	....	100	....	....	....	....	....	....
"	70°	....	....	....	80	20	....	....	....	100	....	....	....	....	....	....
50°	Left at 50°	....	....	100	....	....	....	....	100	....	....	....	....	....	....	....
"	60°	....	....	....	100	....	....	....	....	100	....	....	....	....	100	....
"	70°	....	....	....	90	10	....	....	....	90	10	....	....	....	....	....
50°, Vines Treated with 2,4,5-T	Left at 50° until Mar. 14, then shifted to 60°	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1.5 lbs. per acre		....	....	....	....	....	....	30	60	10	....	....	....	70	30	....
3.0 lbs. per acre		....	....	....	....	....	....	70	20	10	....	....	10	60	30	....

[1] See footnote 1, Table 1.

TABLE 3.—*Effect of tuber size on specific gravity and shrinkage of two varieties during storage*[1]

Variety	Date	1½-2 In.		2-2½ In.		2½-2⅞ In.		2⅞-3¼ In.	
		Specific Gravity	Loss in Weight—Per cent	Specific Gravity	Loss in Weight—Per cent	Specific Gravity	Loss in Weight—Per cent	Specific Gravity	Loss in Weight—Per cent
Green Mountain	Dec. 8	1.070	1.4	1.071	1.3	1.071	2.1	1.073	1.6
	Feb. 2	1.073	2.3	1.074	2.9	1.075	3.7	1.075	3.4
	Apr. 3	1.077	4.2	1.077	5.3	1.075	6.2	1.073	7.3
Katahdin	Dec. 8	1.063	1.3	1.065	1.2	1.066	1.3	1.068	1.7
	Feb. 2	1.067	2.9	1.070	2.7	1.071	3.3	1.071	3.3
	Apr. 3	1.071	5.6	1.073	3.4	1.072	4.4	1.073	5.6
Av., Both Varieties	Dec. 8	1.066	1.4	1.068	1.3	1.069	1.7	1.071	1.7
	Feb. 2	1.070	2.6	1.072	2.8	1.073	3.5	1.073	3.4
	Apr. 3	1.074	4.9	1.075	4.4	1.074	5.3	1.073	6.5
Av., above 3 Dates		1.070	3.0	1.072	2.8	1.072	3.5	1.072	3.9
Av., All 6 Dates		1.070	....	1.071	....	1.072	....	1.073	....

[1] Values are averages for 3 storage temperatures, 36°, 40°, and 50°.

TABLE 4.—*Effect of storage temperature on specific gravity and shrinkage weight of tubers of four potato varieties during storage*[1]

Variety	Date	36°F.		40°F.		50°	
		Specific Gravity	Loss in Weight—Per cent	Specific Gravity	Loss in Weight—Per cent	Specific Gravity	Loss in Weight—Per cent
Green Mountain	Dec. 8	1.072	1.7	1.073	1.9	1.069	1.3
	Feb. 2	1.074	2.5	1.076	3.2	1.073	3.6
	Apr. 3	1.073	4.7	1.078	5.9	1.076	6.6
Kennebec	Dec. 8	1.068	1.3	1.070	1.0	1.068	1.0
	Feb. 2	1.071	2.4	1.071	2.0	1.072	2.9
	Apr. 3	1.072	2.0	1.073	4.5	1.077	6.8
Katahdin	Dec. 8	1.066	1.2	1.066	1.7	1.066	1.2
	Feb. 2	1.071	2.6	1.068	2.8	1.070	3.9
	Apr. 3	1.072	3.7	1.073	5.2	1.073	7.8
Teton	Dec. 8	1.063	1.0	1.064	1.9	1.062	1.6
	Feb. 2	1.066	1.4	1.065	2.6	1.063	3.6
	Apr. 3	1.065	2.3	1.066	4.5	1.065	6.0
Av., all varieties	Dec. 8	1.067	1.3	1.066	1.6	1.066	1.3
	Feb. 2	1.070	2.2	1.070	2.7	1.069	3.5
	Apr. 3	1.071	3.7	1.072	5.0	1.073	6.8

[1] Values are averages of 4 tuber sizes of Green Mountain and Katahdin and 3 of Kennebec and Teton.

April 3. At 50° the Katahdin variety had sprouts about two inches long. Other varieties were sprouted to a lesser degree, but as indicated above, no sprouts were removed prior to weighing. Of the tubers from vines sprayed with 2,4,5-T, the bulk did not sprout at the 50° temperature or when changed to 60° or higher temperatures. A few tubers had sprouts, indicating that the material was not uniformly translocated into all tubers. Marshall and Smith (*2*) have reported variable results of 2,4,5-T sprays in preventing sprouting of several potato varieties. This material, the methyl ester of alpha napthaleneacetic acid, and certain others have been used successfully in most cases to prevent or retard sprouting at storage temperatures of 50° or above at which sugars do not tend to accumulate in potato tubers. The need for a satisfactory low cost, "foolproof" sprout inhibitor for use on potatoes stored for long periods for potato chips or French fries is apparent.

Shrinkage and specific gravity increased on the average in this experiment with increase in tuber size, as shown in table 3. The data for individual varieties and storage temperatures, however, were somewhat variable. The reason for this relationship is not entirely clear, although the rate of respiration in the larger tubers may be greater and therefore result in a greater percentage loss.

Specific gravity of Katahdin tubers from plants sprayed with 2,4,5-T averaged 0.005 lower on March 27 and April 14 than did tubers from untreated plants. This difference is approximately equivalent to one per cent in starch and solids contents of the tubers, which was emphasized by the poorer quality, in regard to mealiness, of the French fries from potatoes treated with 2,4,5-T. These tubers remained firm and brittle throughout the storage period. Other forms, concentrations, or times of applications of 2,4,5-T which will inhibit sprouting, but not reduce quality, may be found.

Summary and Conclusions

Lots of tubers of the Green Mountain, Katahdin, Kennebec, Mohawk, and Teton varieties were sized and placed in storage at 36°, 40°, and 50° in early November, 1949. In January portions of these lots were changed to higher temperatures of storage. Shrinkage and specific gravity were determined at approximately monthly intervals, and French frying tests were made in February, March and April.

Certain varieties rated low in specific gravity were satisfactory for French fries at 50° storage, but none was suitable at 36° or 40°. Reconditioning at 60° or 70° for 20 or 38 days reduced sugars in all lots of tubers sufficiently for satisfactory French fry quality.

Shrinkage increased with time in storage, temperature, and size of tubers. Specific gravity increased appreciably with time in storage and slightly with size of tubers.

Spraying Katahdin potato vines with 2,4,5-T in August retarded sprouting but reduced the quality of the tubers for French fries, both in regard to sugar content and mealiness. Specifc gravity of these tubers was also lower.

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ACID HYDROLYSIS OF POTATOES UNDER PRESSURE*

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INTRODUCTION

An important problem connected with the marketing of potatoes is the utilization of culls and surpluses. There are culls in every crop, and surpluses occur periodically because of fluctuations in yield and acreage. If whole potatoes could be hydrolyzed to give a concentrated self-preserving syrup, it would be possible to utilize these cull and surplus potatoes more efficiently. The syrup might be utilized as a source of fermentable carbohydrates or as feed. Potatoes could be stored and shipped more easily in this form than as whole potatoes.

Considerable information is available on the hydrolysis of pure starch (4), wood cellulose (2, 10), and agricultural residues (1) but not on the hydrolysis of potatoes. Hydrolysis of potatoes is complicated by the presence of proteins, pectins, and hemicelluloses. The pectins and pentosans would be expected to form furfural under the conditions of acid hydrolysis. Small amounts of hydroxymethyl furfural might be formed from the hexoses liberated. The Maillard reaction (5, 6) between amino acids and reducing sugars would likewise be expected.

To determine the feasibility of the acid hydrolysis of potatoes, experiments had been conducted at atmospheric pressure by other workers in this Laboratory. The potatoes were ground in a hammer mill, hydrolyzed in beakers in a steam bath at 90-95° C. to the point where the addition of iodine produced a wine-red color. The buffering effect of ground potatoes is considerable. For example, the pH values of ground potatoes and 1, 3, and 8 per cent of phosphoric acid were 3.2, 2.0, and 1.4, respectively. Corresponding values for water and phosphoric acid were much lower—1.6, 1.3, and 1.0.

Table 1 shows that the starch in potatoes is much more difficult to hydrolyze than starch alone.

In other experiments, carried out at atmospheric pressure in a steam-jacketed kettle with good agitation, hydrolysis with 1 per cent hydrochloric acid (based on the weight of water in the potatoes) required 2 hours to reach the point at which iodine produced the wine-red color. After neutralization with sodium hydroxide, the solids content was 25 per cent. Sodium chloride constituted 5.7 per cent of the solids. Since the hydrolyzate contained only 16.5 per cent of soluble carbohydrates, fermentation took place

*Report of a study made under Research and Marketing Act of 1946.

**One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

TABLE 1.—*Time (hours) required to hydrolyze potatoes and starch at 90°—95°C.*

Acid	Hydrochloric Acid		Phosphoric Acid	
Per cent Acid[1]	Starch	Potatoes	Starch	Potatoes
1	1.9	30.4	7.1	>50
2	1.7	9.8	6.3	42
3	0.8	3.3	6.1	26.4
4	.7	2.7	5.3	14
6	.2	2.5	4.2	13.2
8	.1	2.1	2.1	12

[1] Based on the water content of the mixture.

rapidly. It had to be concentrated to more than 58 per cent total solids before it was self-preserving. At that point it contained about 39 per cent soluble carbohydrates and was a dark-brown, stiff, pasty mass with a bitter taste. A similar hydrolysis with 2 per cent hydrochloric acid required 30 minutes to reach the point of the wine-red reaction and had to be concentrated to 61 per cent solids (about 39 per cent soluble carbohydrates) to prevent fermentation. The 2 per cent acid offset the stiffness resulting from gelatinization of the starch, thus decreasing the power required for stirring. After neutralization, sodium chloride constituted 10.7 per cent of the solids. The stiff, pasty mass was difficult to dry. About 35 per cent solids (22 per cent soluble carbohydrates) was the maximum content that would permit the material to flow freely. This syrup required 0.1 per cent sodium benzoate to prevent fermentation.

It was assumed that hydrolysis under pressure would require less acid or a shorter time than the same process conducted at atmospheric pressure. The lower concentration of acid should result in a lower concentration of salt in the syrup after neutralization. Since the hydrolysis at atmospheric pressure was not satisfactory, we tested these assumptions by studying the hydrolysis under pressure.

EXPERIMENTAL METHODS

Hydrolyses: The washed potatoes were ground to pass through the coarse screen (2-mm. openings) of the Wiley mill. Sixteen pounds (7260 grams) of the ground potatoes were placed in a 2-gallon, glass-lined autoclave, and then the acid was added. The percentage of anhydrous acid was based on the weight of the whole potatoes. After the potatoes and acid were mixed, a sample was taken for a pH determination, and then the mixture was heated by steam in the jacket to the reaction temperature. In most cases, the kettle was closed when the contents started to boil, thus eliminat-

ing most of the air. About 1 hour was required to heat the contents to 130°C. Timing was begun when the mixture reached the desired temperature. The mixture was agitated continuously. At intervals samples were blown out through a sampling tube, and put in sterile pint fruit jars, which were immediately placed in the refrigerator and kept there until the contents were analyzed. Separate small samples were used for the pH determinations which were made with a Beckman Model G pH meter as soon as the sample had cooled. Iodine tests were made on the samples that might contain starch.

Analytical Methods: Moisture was determined by drying the materials to constant weight in a vacuum oven at 70°C. Sugar was determined by the standard A.O.A.C. method (7); the Munson-Walker method was used for determination of reducing power. The results are reported as per cent glucose. Total water-soluble carbohydrates were determined by a modified procedure for direct acid hydrolysis of starch (7). The sample was extracted by decantation through a filter with 300 mls. (50-ml. portions) of water at room temperature. The leaded and deleaded extract was heated for 2.5 hours under reflux on the steam bath with 30 mls. of hydrochloric acid (sp. gr. 1.125). The hydrolyzate was cooled, neutralized and treated as described for the direct acid hydrolysis of starch. The results are reported as per cent glucose. Starch was determined by the method of Steiner and Guthrie (9).

Results

Table 2 shows the analyses of the various lots of potatoes. In table 3 are given the results of the hydrolysis experiments. The batch numbers in tables 2 and 3 show the order in which the analyses and determinations were made. Batches 1-6 represent one sample of potatoes grown in New Jersey, 7-12 represent a sample of Pennsylvania potatoes, 13-16 were from a second lot of Pennsylvania potatoes, and 17-22 were from a sample of Long Island potatoes. The potatoes were grown in the summer of 1948.

The solids in the first five batches (Tables 2 and 3) were probably low. These samples were dried in a forced-draft oven for 2 hours at 65° C. and then for 2 hours at 135° C. Under these conditions, considerable loss by decomposition took place. In batch 2, the whole lot was heated for 2 hours at 130° C. and then cooled by circulating cold water in the jacket. After neutralization to pH 5 with calcium oxide, the mixture was concentrated by heating at atmospheric pressure. In batch 4, 63 per cent of the starch was found in the sample taken when the mixture reached 130° C., 50 per cent in the sample removed after 1 hour, and none in samples taken after 2 hours. In batch 5 the corresponding starch values were 60, 38, and 25 per cent, respectively. Batch 21 contained 11 per cent starch when the temperature reached 130°C.

TABLE 2.—*Analyses of raw potatoes*
(Moisture-free basis)

Batch	Solids Per cent	Reducing Sugar Per cent	Total Sugar Per cent	Total Water-Soluble Carbohydrates Per cent	Starch Per cent	Calculated Hydrolyzable Carbohydrates[1] Per cent
1	19.3	0.3	1.5	1.4	65.7	74.4
6	20.0	<0.1	1.3	1.0	65.7	74.0
7	22.5	0.7	1.3	1.3	70.6	79.7
10	21.1	<0.1	1.3	1.3	74.1	83.5
14	22.9	0.4	....	1.3	69.8	78.9
18	24.4	....	....	2.2	71.2	81.3
22	26.9	0.9	....	3.2	68.4	79.2

[1] Calculated as glucose from the value for starch and water-soluble carbohydrates.

TABLE 3.—*Analyses of potato hydrolyzates*
(Moisture-free basis)

Batch	Condition of Hydrolysis: Acid Kind	Acid Per cent	Temp., °C.	Raw Potatoes	Potatoes with Acid	pH After hours at °C. 0	1	2	4	6	Solids Per cent After hours at °C. 0	1	2	4	6
2	HCl	1.0	130	5.9	1.1	....	....	1.7	....	....	....	....	41.2	....	....
3	HCl	0.5	130	6.0	2.6	2.9	3.1	3.2	3.3	3.2	20.3	19.7	19.3	19.5	18.4
4	HCl	0.3	130	6.0	3.7	3.9	4.0	4.0	4.0	4.2	20.6	20.4	20.1	20.1	19.6
5	HCl	0.7	130	5.9	1.9	2.2	2.5	2.7	2.6	3.0	17.0	17.9	17.7	17.5	16.7
8	HCl	0.7	120	5.7	1.8	1.9	2.1	2.2	2.3	2.4	23.8	23.8	23.8	23.9	23.4
9	HCl	0.5	140	6.1	2.7	3.1	3.2	3.4	3.3	3.0	24.1	23.8	23.5	22.5	21.4
11	HCl	1.0	120	5.9	1.1	1.3	1.4	1.5	1.8	1.5	24.2	23.8	23.8	23.2	23.1
12	HCl	1.0	110	5.8	1.1	1.1	1.1	1.3	1.3	1.4	23.8	23.6	23.5	23.5	23.0
13	HCl	0.7	140	6.2	1.9	2.7	2.7	3.0	3.0	2.6	23.8	23.3	22.8	22.0	21.5
15	H_2SO_4	0.54	130	6.1	3.3	3.5	3.5	3.7	3.6	3.7	24.1	23.7	23.8	....	24.2
16	H_2SO_4	1.5	130	6.1	1.4	1.5	1.7	1.8	1.7	....	25.8	25.5	25.0	24.0	23.4
17	H_2SO_4	1.1	130	6.0	1.8	1.9	2.0	2.2	2.2	2.3	27.2	26.8	26.5	25.8	25.2
19	H_3PO_4	6.0	130	6.3	1.4	1.4	1.4	1.6	1.7	1.9	30.4	29.6	27.5	26.3	25.8
20	H_3PO_4	4.5	130	6.2	1.9	1.8	1.9	1.9	2.0	1.8	30.2	28.8	27.4	26.0	25.0
21	SO_2	2.0	130	6.3	2.7	3.5	3.3	3.2	2.8	2.5	28.0	27.5	27.8	27.9	27.5

TABLE 3.—*Analyses of potato hydrolyzates (Continued)*
(Moisture-free basis)

Batch	Condition of Hydrolysis			Reducing Sugar Per cent					Total Cold Water-Soluble Carbohydrates, Per cent				
	Acid			After hours at °C.					After hours at °C.				
	Kind	Per cent	°C.	0	1	2	4	6	0	1	2	4	6
2	HCl	1.0	130	....	....	74.4	....	....	....	....	74.4	....	....
3	HCl	0.5	130	6.4	20.1	28.2	39.7	47.0	62.3	85.4	85.4	79.4	76.4
4	HCl	0.3	130	2.1	3.4	4.6	7.5	8.7	13.7	36.5	57.5	69.5	78.0
5	HCl	0.7	130	28.1	58.1	73.3	76.3	79.4	99.9	92.2	89.9	81.4	78.6
8	HCl	0.7	120	16.4	42.3	54.5	61.7	64.8	77.9	78.1	77.0	71.7	69.5
9	HCl	0.5	140	10.6	21.4	31.2	43.2	52.2	77.8	77.2	72.7	65.3	58.1
11	HCl	1.0	120	51.1	71.3	72.5	73.9	73.1	78.6	79.0	77.0	77.3	75.0
12	HCl	1.0	110	24.2	54.9	63.2	68.6	71.5	77.1	76.0	76.3	75.6	75.9
13	HCl	0.7	140	40.6	60.5	65.3	66.0	64.0	77.8	74.4	71.7	65.9	64.2
15	H_2SO_4	0.54	130	2.1	....	5.1	....	11.5	16.0	....	53.4	....	73.9
16	H_2SO_4	1.5	130	13.3	42.7	56.4	61.7	61.7	75.9	75.2	70.1	62.3	57.1
17	H_2SO_4	1.1	130	7.3	25.2	35.8	48.8	55.9	59.8	78.8	77.6	71.6	66.8
19	H_3PO_4	6.0	130	25.6	54.3	56.5	50.1	43.0	66.6	60.5	54.5	43.1	35.3
20	H_3PO_4	4.5	130	14.4	49.5	57.2	56.1	48.8	69.9	65.5	58.2	46.6	40.0
21	SO_2	2.0	130	6.0	11.5	18.6	33.0	46.9	46.8	76.2	76.8	69.8	64.3

Discussion of Results

Figure 1 illustrates the changes which took place during the hydrolysis of batch 3. The pH change on addition of acid is shown at the left of the vertical axis. The pH gradually increased as hydrolysis proceeded, perhaps because of formation of salt with the amino acids freed. The starch had nearly disappeared by the time the mixture reached the temperature of the experiment and nearly all of it had been converted to water-soluble forms. The value for water-soluble carbohydrates reached a maximum value and then began to decrease as heating progressed. This loss in reducing power indicated decomposition of the sugars. At the same time, the pressure in the autoclave continued to increase (at constant temperature). The gas in the autoclave responsible for the increase of pressure contained carbon dioxide. When decomposition was considerable, the pressure in the kettle rose to two or three times that of saturated steam at the temperature used. The hydrolysis to glucose was not complete after 6 hours. If the hydrolysis were complete, the curves for sugar and water-soluble carbohydrates would meet and then coincide. It is important to note, however, that the hydrolysis brought about complete conversion of the starch to a water soluble form after 1 hour. For some uses, this might be a good stopping point, avoiding the unnecessary decomposition of carbohydrate material.

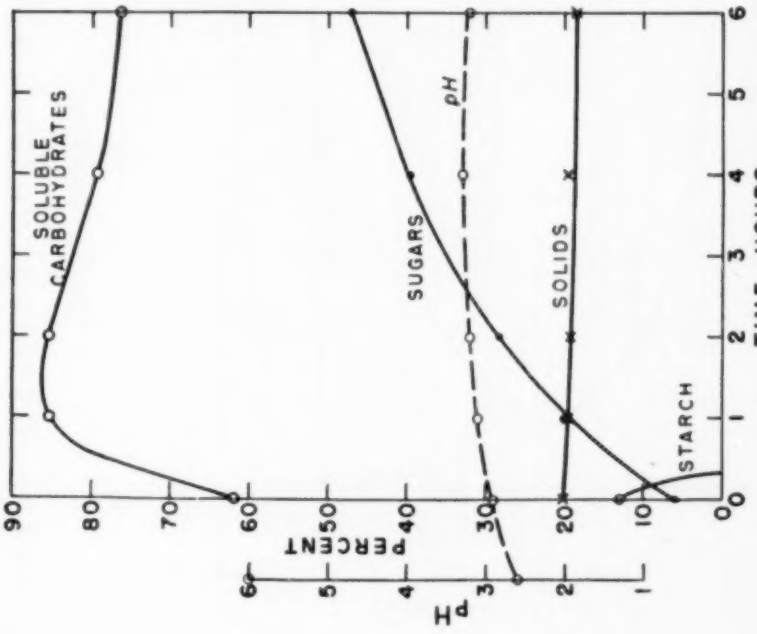

Fig. 1, Hydrolysis with 0.5% HCl at 130° C. (Batch 3)

The results represented by figure 1 are more or less typical. Figure 2 shows the results when hydrolysis was practically complete in 6 hours (batch 12). The maximum gauge pressure in this case was 12 pounds, and little decomposition occurred. In figure 3 is illustrated another example of practically complete hydrolysis in 6 hours. Here, however, with a lower concentration of acid and a higher temperature than in batch 12 (Figure 2), the loss in reducing power was more than 25 per cent in 6 hours. That this loss was caused mainly by the increase in temperature was confirmed by the following experiment: A batch of potatoes was hydrolyzed under the conditions used for batch 12, illustrated in Figure 2. After 6 hours heating at 110°C. the mixture was cooled and neutralized to pH 5 with sodium hydroxide, and then heated at 140°C. After 6 hours' further heating, the reducing power had dropped to less than one-half the value shown in figure 2.

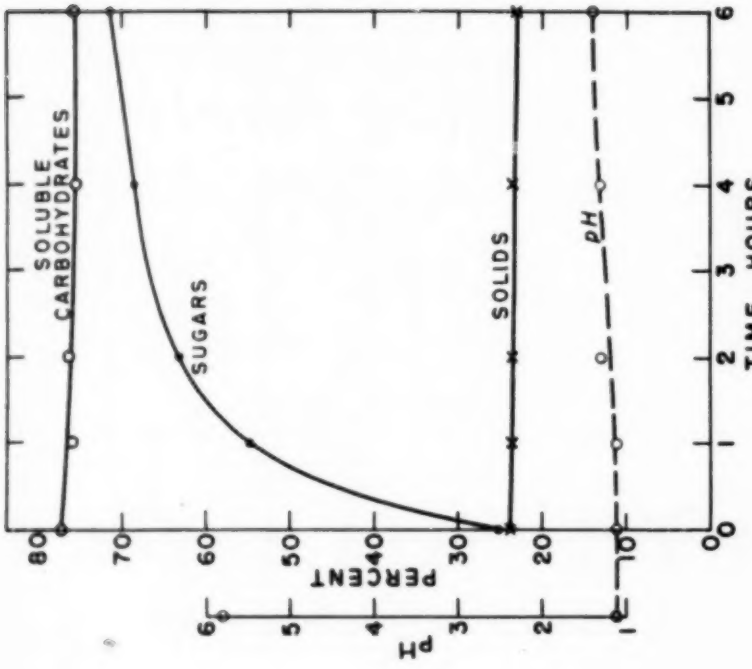

Fig. 2. Hydrolysis with 1.0 % HCl at 110° C. (Batch 12)

With acids other than hydrochloric, the results were similar except that the loss in reducing power was greater. The results with sulfuric acid were not far different from those obtained with hydrochloric acid, but larger amounts of sulfuric acid were needed to achieve the same results. Still larger amounts of phosphoric acid were required. Figure 4 shows the results of one run with phosphoric acid. As compared with results of hydrolysis with corresponding amounts of hydrogen chloride, loss in reducing power was greater, loss in solids occurred, the pH remained more constant, and the curves representing sugar and water-soluble carbohydrates cross. In hydrolyses with hydrogen chloride, these curves approached each other or even coincided, but they do not cross in any case, nor would they be expected to cross.

The significance of the crossing of the curves in the case of phosphoric acid is not clear. Control experiments were run in which glucose solutions with and without sodium phosphate were analyzed according to these procedures. The same results were obtained with both solutions, indicating that the crossing of the curves was not due to errors in analysis caused by the presence of phosphate or phosphoric acid.

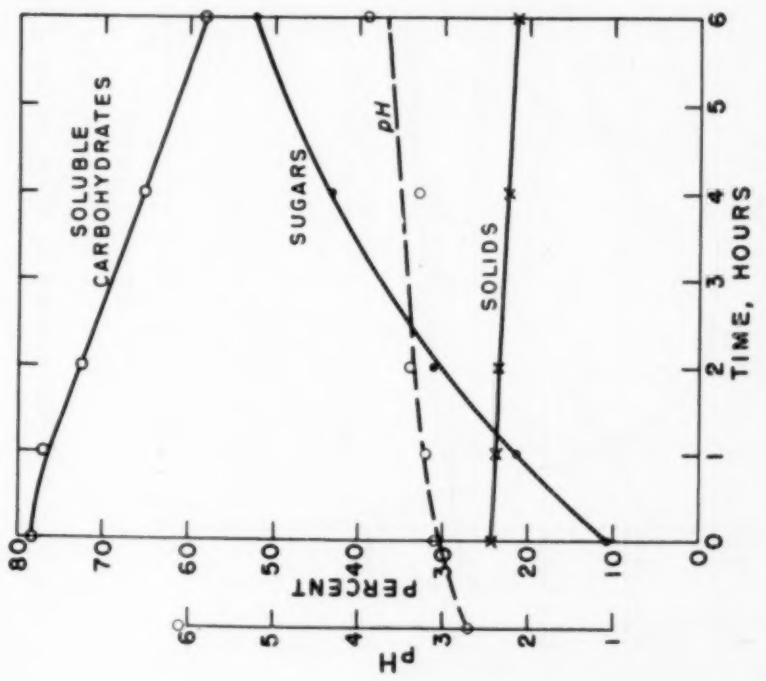

Fig. 3. Hydrolysis with 0.5% HCl at 140°C. (Batch 9)

Sulfur dioxide was tried with the results shown in figure 5. In contrast with results with the other acids, the pH value decreased with progress of heating. Perhaps the sulfurous acid was converted to a stronger, possibly non-volatile acid. The solids content remained constant.

In figure 6 are summarized the effects of the various acids on the rate of formation and decomposition of reducing sugar. In all the hydrochloric acid experiments, there was a continuous increase in the reducing value. As previously mentioned, the values for 0.7 per cent hydrochloric acid were somewhat high because of errors in determining solids. With 1.5 per cent sulfuric acid, the curve flattened out, and with phosphoric acid the reducing value reached a maximum and then decreased, indicating decomposition. In figure 7, in which total water soluble carbohydrate content is plotted against time, the tendency of the acids to cause loss in reducing power is shown more strikingly. Here again the rate of decrease in reducing power was least with hydrochloric acid. In order of increasing effect the catalysts were: hydrochloric acid, sulfuric acid, sulfur dioxide, and phosphoric acid. In fact, with the higher concentrations of sulfuric and phosphoric acids,

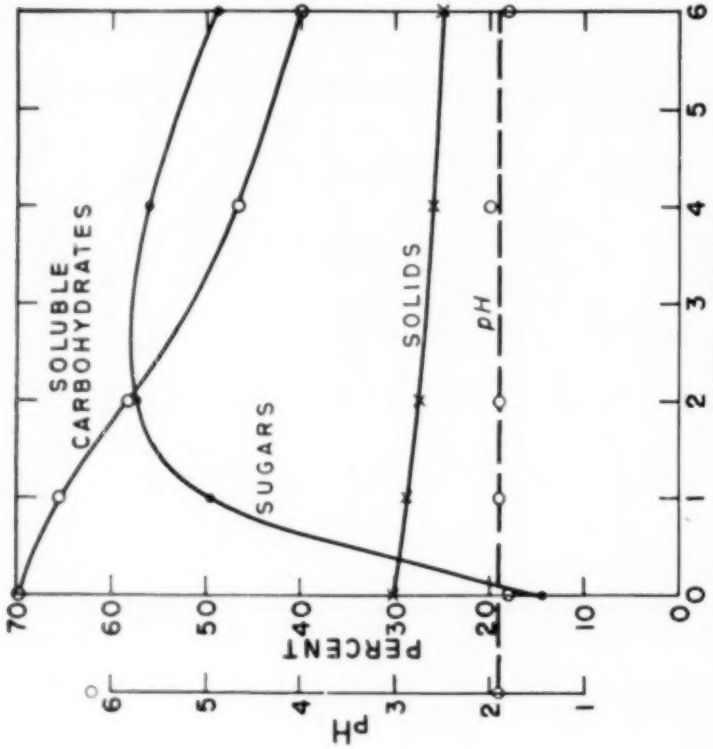

Fig. 4. Hydrolysis with 4.5 % H_3PO_4 at 130° C. (Batch 20)

the yields were lower, although the maximum was reached sooner. It may be noted that 0.7 per cent hydrochloric acid, 1.1 per cent sulfuric acid, and 4.5 per cent phosphoric acid produced mixtures having a pH of approximately 1.9. The curves for the three acids, however, are quite different.

In a number of cases a plot of the logarithm of the percentage residual potential reducing sugar (the difference between sugar and total water soluble carbohydrates in per cent of the latter) against time gave straight lines, indicating that the rate of hydrolysis followed a first-order reaction; that is, the rate depended only on the concentration of the unhydrolyzed carbohydrate if the acid concentration and temperature were constant (8, 3). In other cases, such lines were somewhat curved. To obtain a better idea of the relative rates, the reaction constants were calculated from the slopes of the lines. No great accuracy is claimed for the constants; they are given only to indicate the relative rates of reaction. The constants (time in hours, natural logarithms) are listed in table 4. When only one value is given, the value was constant throughout the range studied; otherwise a range of values is given. With hydrogen chloride and a temperature of approximately 130°C., an increase of 20° about doubled the rate of reaction.

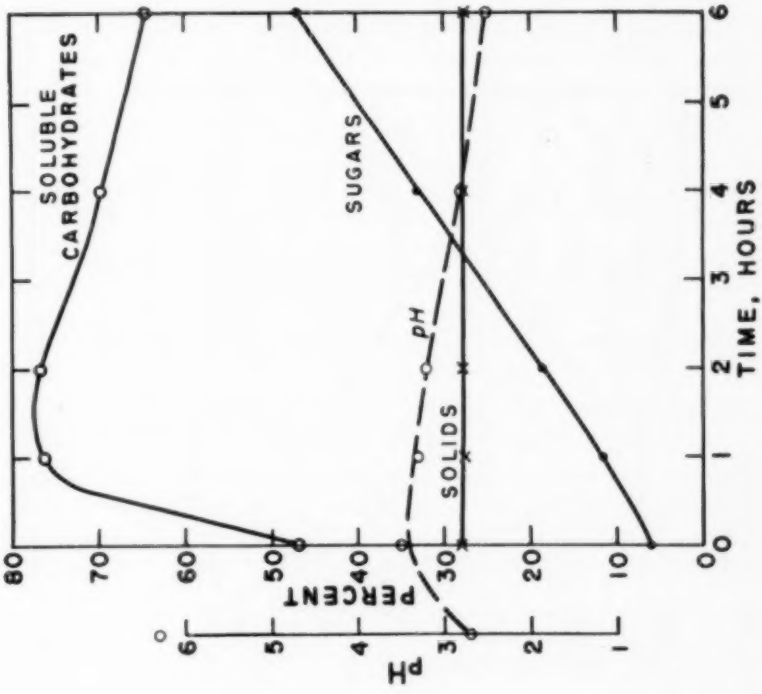

Fig. 5. Hydrolysis with 2.0% SO_2 at 130°C. (Batch 21)

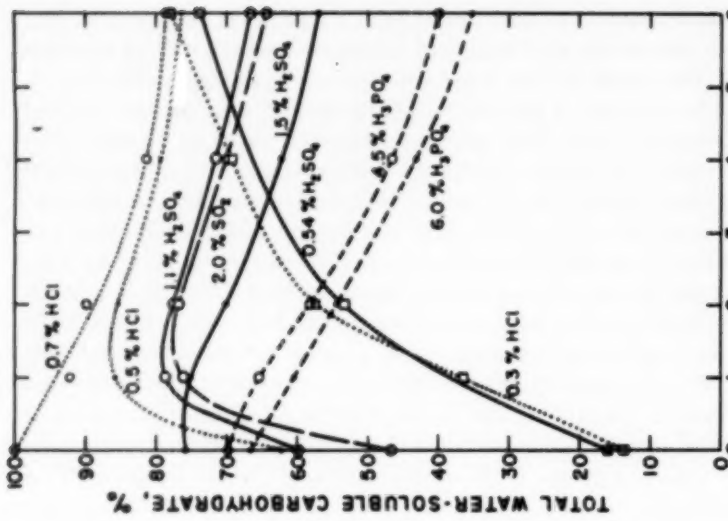

Fig. 7 Effect of acid on total water-soluble carbohydrate yield.

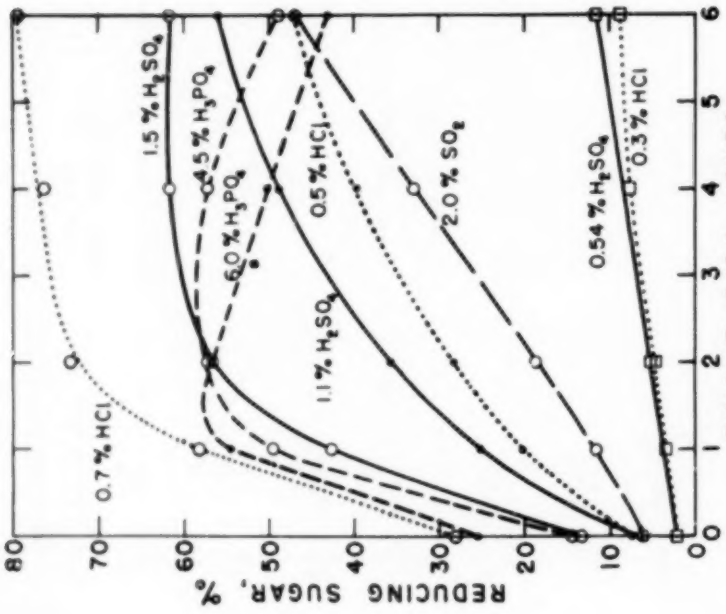

Fig. 6 Effect of acid on reducing sugar yield.

TABLE 4.—*Relative reaction rates.*

Batch	Acid		Temperature-°C.	Rate Constant hr^{-1}
	Kind	Per cent		
19	H_3PO_4	6.0	130	1.8—?
20	H_3PO_4	4.5	130	1.2—0.36?
11	HCl	1.0	120	1.3—0.21; 0.44 av.
13	HCl	0.7	140	0.86
12	HCl	1.0	110	0.90—0.23; 0.41 av.
5	HCl	0.7	130	0.62
16	H_2SO_4	1.5	130	0.54
8	HCl	0.7	120	0.41
17	H_2SO_4	1.1	130	0.25
21	SO_2	2.0	130	0.025—0.33; 0.20 av.
9	HCl	0.5	140	0.24
3	HCl	0.5	130	0.14
15	H_2SO_4	0.54	130	0.026
4	HCl	0.3	130	0.014

Increasing the concentration from 0.3 to 0.5 per cent hydrogen chloride increased the rate about tenfold. An increase from 0.5 to 0.7 per cent tripled the rate, and an increase from 0.7 to 1.0 per cent increased the rate two to three times. Approximately the same rate was obtained with 1.5 per cent sulfuric acid as with 0.7 per cent hydrogen chloride, and this was nearly doubled with 4.5 per cent phosphoric acid.

Hydrochloric acid is used as a catalyst in the commercial acid hydrolysis of starch (4). Work on the hydrolysis of wood cellulose (3) and that reported here indicate that in both cases hydrochloric acid is more efficient than sulfuric acid. In large scale tests on both wood (2) and agricultural residues (1), however, sulfuric acid has been used, probably because it is the cheapest acid. The relative prices/ (per hundred pounds) on a water-free basis are: sulfuric acid, \$0.89; sulfur dioxide ,\$4.50; hydrochloric (muriatic) acid, \$5.92, and phosphoric acid, \$6.00. Sulfur dioxide would be rather expensive, since a large quantity would be required, but part of it at least might be removed by volatilization, thereby decreasing the amount of salt retained in the final product after neutralization.

The products of the hydrolyses described here were dark and bitter. The material was difficult to concentrate beyond 40-45 per cent solids because it became a stiff, sticky paste. At this concentration, it was not self-preserving because it contained only about 30-35 per cent of sugars. Concentrated samples molded in the laboratory.

/The lowest prices calculated from the prices listed in the Oil, Paint, and Drug Reporter for November 28, 1949.

Conclusion

The acid hydrolysis of potatoes does not appear promising as a method of processing cull and surplus potatoes for storage or transportation. Elevated pressures do not seem to have much advantage, although they produce results in a shorter time or with less acid. To avoid decomposition, high acid concentrations would be required, and the resulting syrups would be difficult to concentrate. The statement, "In order to be suitable for commercial use, the agent promoting hydrolysis must give a high rate of hydrolysis as compared with the rate of sugar decomposition" (3) applies with the same force to the hydrolysis of potatoes as to the hydrolysis of wood cellulose. The rate of decomposition of potato hydrolyzates seems to increase more rapidly with temperature than the rate of hydrolysis, and the ratio is more favorable for wood cellulose than for potatoes. This method of hydrolysis is more promising when the hydrolyzates are to be used as fermentation substrates and when it is not necessary to hydrolyze the starch completely to glucose. Relatively high acid concentrations and close control would be required to keep decomposition to a minimum. Under properly controlled conditions, the results might well be satisfactory. Use of the material as a fermentation substrate would not require the expensive concentration step.

Acknowledgements

The authors are indebted to R. H. Treadway and P. W. Edwards for the data on the hydrolysis of potatoes at atmospheric pressure, and to C. H. Fisher and E. Yanovsky for their advice and encouragement.

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THE UTILIZATION OF PHOSPHORUS BY TWO POTATO VARIETIES ON LONG ISLAND[1]

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Previous studies (2,3)[4] have indicated that little benefit is being derived from the large quantities of phosphorus applied every year to the Long Island potato crop. By using phosphatic fertilizers labeled with P^{32} it was shown (1, 2) that as the phosphorus application was increased the percentage of phosphorus in the plant from the fertilizer also increased. Also as the amount of phosphorus in the soil increased, the percentage of phosphorus in the plant from the fertilizer decreased. However, with an application of 200 pounds per acre of P_2O_5 on soils low in phosphorus, on Long Island only eleven pounds of fertilizer P_2O_5 were used by the crop (2). Work in Maine (1) with the Katahdin variety and in North Carolina (2) with Irish Cobbler showed response curves different from those obtained on Long Island with Green Mountain (2).

This report concerns an experiment on Long Island in 1949 designed to determine whether the varieties Irish Cobbler and Green Mountain had different phosphorus utilization curves when grown under the same conditions.

MATERIALS AND METHODS

The experiment was conducted on a Sassafras loamy sand having a medium level of phosphorus for the area. Phosphorus was added at rates of 0, 100, and 200 pounds of P_2O_5 per acre. Nitrogen and potash were added at a constant rate of 100 pounds per acre. All fertilizers were placed in bands 3 inches to the sides of and 2 inches below the seed piece. Two varieties, Irish Cobbler and Green Mountain, were grown at each phosphorus level giving six treatment combinations.

All plots were six rows wide and 40 feet long. One row of every plot was used for final yield measurements, two rows received the labeled fertilizer and three rows were used for guards. Five replicates in a randomized block design were used. Seed pieces were placed six inches apart in the radioactive rows to provide extra plants for the first two samplings.

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[4] Numbers in paranthesis refer to literature cited at end of paper.

Six sets of samples were taken from the radio-active rows. The first sample was one-half of the extra plants in the plot and the second half was the remaining extra plants. The rows were then divided into four 9 foot sections, leaving 2 feet at each end for guards. These sections provided the samples for the next four dates. Tops were taken at all sampling dates and tubers were also taken on the fifth date for Cobbler and the last, or sixth date, for Green Mountain. The dates of the field operations are given in table 1.

TABLE 1.—*Dates of field operations*

Operation	Date	Stage of Growth	
		Cobblers	Green Mountains
Planted	May 5, 1949		
1st Sample	June 3,	3"-4" high	3"-4" high
2nd Sample	June 15,	6"-10" high	6"-10" high
3rd Sample	June 29,	Early bloom	Bud
4th Sample	July 14,	Full bloom	Early bloom
5th Sample	July 27,	Before leaves mature	Full bloom
6th Sample (Gr. Mt. only)	Aug. 22,	.....	Before leaves mature
1st Irrigation	July 2,	Early bloom	Bud
2nd Irrigation	July 21,	Completed blooming	Mid-bloom

The fertilizer material containing p^{32} was prepared by the U.S.D.A. Plant Industry Station at Beltsville, Maryland. The assays of plant samples for P^{31} and P^{32} were also conducted in the laboratories at the Plant Industry Station. The sixth sample was taken too late to assay for P^{32} because of the reduced activity.

RESULTS AND DISCUSSION

Percentage of Phosphorus in the Plant Derived from the Fertilizer

The percentage of phosphorus in the plant derived from the fertilizer was higher for the 200-pound rate of application than for the lower one (Figure 1.). There was a significant difference between the rates at each sampling date. Near the end of the season the difference between the two varieties also became significant. Irish Cobbler plants contained a higher percentage of phosphorus from the fertilizer than did Green Mountain.

The phosphorus absorption curves for these two varieties differed considerably from previous observations (2). The usual curve shows a rise from the first to second sampling and then a sharp drop levelling off near the end of the season. The sudden rise in 1949 between the third and

fourth sampling dates coincided with an application of 1.5 inches of irrigation as indicated in figure 1. The growing season of 1949 was very dry and the irrigation evidently renewed growth considerably, bringing about a sharp rise in phosphorus absorption.

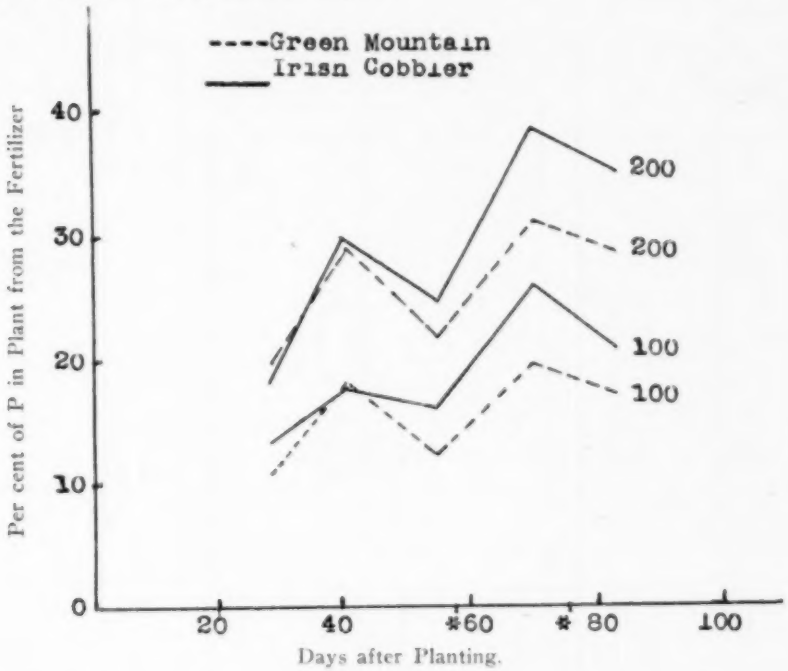

Figure 1.—Percentage of phosphorus in the plant derived from the fertilizer as affected by rate of applied phosphorus.

*Dates Irrigated.
Difference between rates significant at each date.
Difference between varieties significant at last two dates.

The fifth sampling showed the expected decrease late in the season when the major absorbing portion of the root system had grown beyond the fertilizer bands. The varietal difference is in general agreement with the previous reports (2, 3) that Irish Cobbler responded better to phosphorus applications and derived a higher proportion of plant phosphorus from the fertilizer than did Green Mountain.

Pounds of P_2O_5 Absorbed from the Fertilizer and from the Soil

The amount of phosphorus applied greatly influenced the amount absorbed from the fertilizer (Figure 2). Likewise there was more total phosphorus absorbed from the soil and fertilizer combined at the high

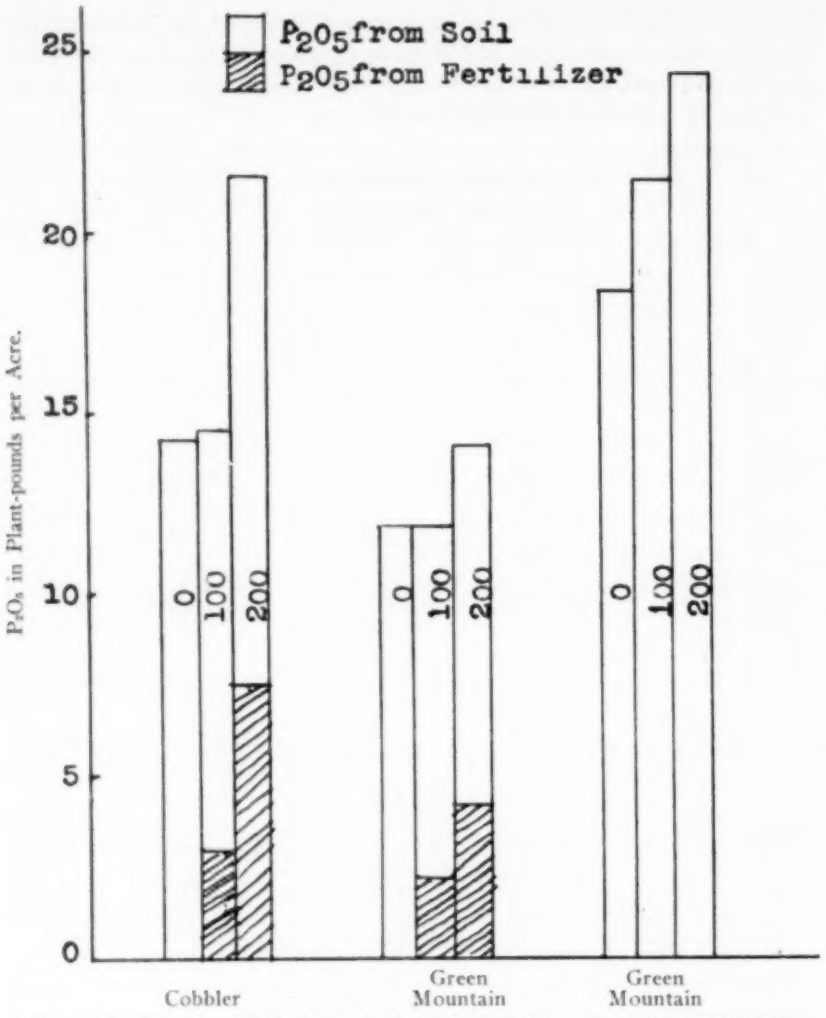

Figure 2.—Uptake of P_2O_5 from the fertilizer and from the soil as affected by rate of application and variety.

(1) At fifth sample, tubers not included.

(2) At sixth sample, tubers included. Amount derived from fertilizer not determined because activity of P^{32} was too low at this time.

rate of application than the low rate. The difference between rates did not begin to be apparent until fairly late in the growing season as shown in table 2. A large part of the difference in phosphorus uptake between no phosphorus added and 200 pounds P_2O_5 per acre could be accounted for by the phosphorus absorbed from the fertilizer.

TABLE 2.— *Phosphorus in the plants from the fertilizer and total phosphorus in the plants at various stages of growth*

		P_2O_5 in the Plants from Fertilizer Lbs/A					Total P_2O_5 in Plants Lbs./A					
		Sampling Date					Sampling Date					
		1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th	6th
Cobblers	0	0	0	0	0	0	1.7	2.9	4.4	5.0	14.5	
	100	0.2	0.5	0.7	2.0	3.0	1.2	3.1	4.5	7.6	14.8	
	200	0.3	1.1	1.3	3.0	7.6	1.7	3.7	5.5	7.8	21.7	
Green Mountains	0	0	0	0	0	0	1.0	2.8	4.9	10.0	12.0	18.5
	100	0.1	0.6	0.7	2.0	2.1	1.3	3.1	5.8	10.4	12.0	21.5
	200	0.2	1.0	1.3	4.0	4.1	0.9	3.3	6.4	13.2	14.2	24.3

These results agree fairly well with previous work (2). However, in 1948 the rate of application seemed to have no influence in the total amount of P_2O_5 in the crop even though there was a marked increase in the amount utilized from the fertilizer. This difference in response may be explained by the fact that 1949 was very dry and the amount of growth was considerably less than in 1948.

There was a higher percentage of phosphorus in the plants grown with phosphorus in the fertilizer than when none was added (Table 3). However, with the Green Mountain variety in 1949 there was a significant difference only at the second, fourth and sixth dates. This differs slightly from the Long Island results in 1948 (2). The Cobbler results in 1949 compare rather well with the North Carolina results in 1948 (2).

In view of the fact that only about 8 pounds of P_2O_5 were used from the 200 applied in the fertilizer, it is evident that soils which are cropped with potatoes every year and heavily fertilized will soon build up a large reserve of phosphorus. This fact has appeared in similar form in experiments in Maine, in 1947 (1); North Carolina, in 1948 (2); and on Long Island in 1948 (2). Thus the inference may be made that fertilizers with a 1-1-1 ratio of nitrogen, phosphorus, and potash may be used to good advantage in place of the 1-2-1 ratio now recommended.

Effect of Phosphorus Application on Yield

The yields of potatoes were not affected significantly by the phosphorus applications as can be seen in table 4. This is in line with the results of 1948 (2) and also other fertilizer experiments on Long Island (3).

TABLE 3.— *Percentage total P_2O_5 in the plants*
(Oven-dry Basis)

Variety	Amount of P_2O_5 applied	Sample						
	Lbs./A	1st	2nd	3rd	4th	5th	6th	Tubers
Cobbler	0	1.25	0.99	0.66	0.65	0.65	(1)	0.64
	100	1.27	1.05	0.74	0.85	0.80	(1)	0.76
	200	1.27	1.15	0.77	0.81	0.79	(1)	0.79
Green Mountain	0	1.26	0.98	0.70	0.75	0.73	0.32	0.80
	100	1.33	1.09	0.80	0.83	0.74	0.37	0.84
	200	1.31	1.19	0.79	0.88	0.84	0.41	0.90
L.S.D. (.05)		N.S.	0.08	0.11	0.11	0.13	0.07	0.13
C. V. (Per cent)		6	6	11	11	13	16	13

(1) Crop was mature at this time. No samples were taken.

TABLE 4.—*Yield of U. S. No. 1 tubers as influenced by phosphorus application*

Variety	Pounds of P_2O_5 per Acre Added	Yield in Bushels Per Acre
Cobbler	0	149
	100	153
	200	193
Green Mountain	0	180
	100	169
	200	160
L.S.D. (0.5)		50
C.V. (Per cent)		24

SUMMARY

The effect of rate of phosphorus application on utilization of phosphorus by Irish Cobbler and Green Mountain varieties of potatoes was studied.

The percentage of phosphorus in the plant derived from the fertilizer increased with higher rates of application of phosphorus.

Irish Cobbler potato plants contained a higher proportion of fertilizer phosphorus at the end of the season than did Green Mountain.

More pounds of P_2O_5 per acre were absorbed from the fertilizer when 200 pounds of P_2O_5 were applied than when 100 pounds were applied.

Less than 5 per cent of the phosphorus applied to the crop was utilized by the plants.

No significant yield responses were noted with either variety to either 100 or 200 pounds P_2O_5 per acre compared to none added.

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THE EFFECT OF A MILD STRAIN OF LATENT MOSAIC VIRUS X ON YIELD OF SOME OF THE NEW POTATO VARIETIES IN MAINE

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(Accepted for publication July 13, 1950)

Latent Mosaic caused by virus X is carried by most of the old potato varieties. The symptoms are inconspicuous in most varieties, and it is almost impossible to detect plants with virus X in the field. Virus X may be readily transmitted to some varieties in the field through contact; but a few varieties, including Kennebec, Katahdin, Sebago, Teton, and Menominee, are somewhat resistant. Several strains of virus X have been isolated. Studies on yield reductions due to the presence of this virus in seed stock indicate that the percentage of reduction varies with the strain of the virus and also with the potato variety.

In Australia, Bald and Norris (2) found that latent mosaic in President and Up-to-Date varieties reduced the yield about 30 per cent. In Scotland, Scot's (6) studies indicated yield reductions of 16 to 25 per cent because of this virus. Smith and Markham (7) stressed the necessity for knowing whether the strains of the virus itself materially reduce the yield. Considering Bald's (1) results in which a very mild strain of virus X was found to cause a highly significant reduction in yield, we must assume that a decrease in yield in some varieties may occur with even the mildest

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strain of virus X. Schultz and Bonde (5) found that latent mosaic in Chippewa reduced the yield 13 to 14 per cent and in Katahdin 12 to 22 per cent, that yield is depressed more in Katahdin than in other varieties tested, and that the reduction in yield is influenced by the strain of virus X.

Clinch and McKay (3,4) in testing the effect of two different mild strains of virus X on the Up-to-Date potato, 1946 found that no reduction in yield resulted from infection with a mild X. In 1948 a test was made with healthy and X-infected plants of two different stocks of Up-to-Date derived originally from two virus-free tubers. Also included in the test were two infected stocks of Up-to-Date from which the strains of X had been isolated. General conclusions for the two years indicated that from the standpoint of yield different stocks react differently to infection with mild strains of virus X, and that in some cases the nature of the reaction may be affected by environmental conditions.

Experimental Procedure

To test the effect of latent mosaic on yield in Chippewa, Sequoia, Sebago, and Teton, stocks free from virus X, as well as material carrying virus X, were selected from tubers indexed in the greenhouse at Beltsville, Maryland, in 1945. One hundred tubers of each variety were indexed, and a seed piece was planted from each numbered tuber. Later when the plants were of a suitable size, inoculations were made to *Datura stramonium* by using a petiole from each potato plant. All plants not showing infection on *Datura*, were inoculated to pepper. All tubers not showing infection on *Datura* but showing infection on pepper plants and also those failing to show infection on pepper plants were tuber-unitted and planted in the fields in Maine. Two isolated plots were used for increasing the material. The plants not producing infection on either *Datura* or pepper were considered X-free, and those failing to inoculate *Datura* but showing infection on pepper were classed as mild X. Ten of the best units, as judged by yield and freedom from X, were selected from the X-free plot the first year. All units of mild-X not showing symptoms on *Datura* were increased the second year. The mild-X material was not carried on as tuber-units. Careful isolation was maintained, and all stocks were early-harvested. Random samples from each plot were taken every fall, and these were re-tested at the greenhouse in Beltsville, Maryland. Material from both mild-X and X-free plots were found to be 100 per cent satisfactory for a yield test.

The experiment consisted of seed of X-free, mild-X, and commercial stock. The experiment was set up as a randomized plot of 12 rows and 5 blocks. Each row consisted of 54 plants spaced 12 inches apart. Seed was cut about ten days before planting and suberized. The experiment was planted on a plot of land on which a heavy stand of clover sod had been turned under the previous fall.

Cultural Program

The cultural program was that usually followed in Aroostook County, Maine. Cultivation began as soon as the plants emerged and continued at weekly intervals until the plants were about in full bloom and the vines nearly closed the rows. Spraying consisted of a fungicide plus DDT applied weekly until frost killed the plants. Since the percentage of virus X in the commercial stock used in this experiment was unknown, 50 plants of each lot in one block were tested by inoculation in the greenhouse. Inoculations were made on *Datura stramonium* and pepper (*Capsicum, sp.*) from representative leaf petioles of each plant. Results are recorded in table 1. A killing frost occurred on September 10, and the experiment was harvested on September 20. At this time all foliage was dead; however, about 90 per cent of the stalks were still green. After harvest the potatoes were held in barrels in the potato house for about ten days and then graded over a 1¾ inch screen into primes, seconds, and culls, but the seconds and culls were weighed as one unit.

Table 1.—*Percentage of virus X on commercial stock.*

Variety	Virus X		
	On Datura	On Pepper	Free from
	Per cent	Per cent	Per cent
Chippewa	86	14	0
Sequoia	74	14	12
Sebago	68	14	18
Teton	28	24	48

Table 2.—*Mean yield in bushels per acre of primes.*

Kind of Seed[a]	Yield of Primes per Acre				
	Chippewa	Sequoia	Sebago	Teton	Mean[a]
	Bus.	Bus.	Bus.	Bus.	Bus.
X-free	625.4	563.7	552.8	614.0	588.9
Mild-X	587.2	551.8	529.5	555.6	556.0
Commercial stock	582.7	562.8	498.7	582.7	556.7
Mean yield[b]	598.3	559.4	527.0	584.1	

Coefficient of varibility 8 per cent

[b] L. S. D. for varieties, 32.8 bushels per acre.

[a] L. S. D. for kinds of seed, 27.9 bushels per acre.

[a] L. S. D. for 2 kinds of seed in 1 variety, 56.8 bushels per acre.

Discussion

By analysis of variance, varieties were significant to the 5- and 1- per cent point. The kinds of seed were significant only to the 5- per cent point. Mean yields in table 2 show a high yield of primes for the four varieties Chippewa, and Teton giving significantly higher yields than Sequoia or Sebago. There are no significant yield differences between Chippewa and Teton or between Sequoia and Sebago.

A comparison of the mean yields for "Kinds of Seed" shows that X-free seed yielded significantly higher than mild-X and commercial seed, but the latter two failed to show a significant yield difference. Moreover, the general trend among the yields of the four varieties indicates that X-free seed produces higher than mild-X or commercial seed. Comparing the yield from two kinds of seed of one variety, there is only one case where the yield differences are significant: X-free seed of Teton gave 58.4 bushels per acre more than the mild-X seed. Comparing the yields from mild-X seed with the yield from commercial seed there is no variety that shows a significant difference in yield between these two kinds of seed. Although not significant the yield from Sebago seed carrying mild-X was 30.8 bushels, or 9.8 per cent higher than the yields from the same variety of commercial seed. The difference in yield that occurred between the two seed sources may be due to the fact that commercial Sebago seed generally carries a relatively virulent strain of virus X. On the other hand, the yield from commercial seed stock of Teton is 27.1 bushels higher than the yield from mild-X seed stock. This increase may be and probably is because this particular lot of commercial stock of Teton had 48 per cent of the plants free from X.

Summary

The reduction in yield from potato seed infected with virus X reported by several investigators varies from a very small amount to as high as 30 per cent. The reduction varies with the potato variety and the strain of virus X.

In an experiment with the varieties Chippewa, Sequoia, Sebago, and Teton, seed stock carrying a mild strain of virus X and stock free from virus X were compared with commercial stock for each variety. Both mild-X and commercial seed gave reduced yields in comparison with yields from stock free from virus X. The reduction in yield varied with the variety. Percentage reductions in yield for mild X were: Chippewa, 6.1 per cent, Sequoia, 2.1; Sebago, 4.2; and Teton, 9.5. Percentage reductions in yield for commercial stock were: Chippewa, 6.8 per cent; Sequoia, 0.2; Sebago, 9.8; and Teton, 5.1. In only two cases did the reduction in yield reach or closely approach significance *viz.*, Teton mild-X and Sebago commercial stock. The yield trend for all varieties favored X-free stock.

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Earle Volcart Hardenburg

Dr. E. V. Hardenburg, Professor of Vegetable Crops at Cornell University, died very suddenly at his home in Ithaca, on the 4th of December. Dr. Hardenburg was an outstanding and most inspirational professor, and his contributions to the potato industry are not only widely known but will long be remembered.

Two days before his death, Dr. Hardenburg was elected a life member of the Potato Association of America and his citation will appear in the next issue of our Journal.

AMERICAN POTATO JOURNAL

Author Index

Vol. 27 Nos. 1-12

Adams, J. B. and R. A. Kelley. Potato aphid control studies, 1946-1949, at Woodstock, N. B., Canada 175-182.
Baerecke, G. L. see Ross, H.
———— see Rudorf, W.
Binkley, A. M., see Kunkel, R.
Bonde, Reiner, Eugene S. Schultz honored by the Potato Association of America. 159-160.
Callbeck, L. C. Further studies on copper sulphate-lime ratios in Bordeaux Mixture. 327-331.
Campbell, J. C., see Maclinn, W. A.
Cole, B. I., see Paul
Cunningham, C. E., see Terman, G. L.
Davis, A. C., see Rawlins, W. A.
Dean, L. A., see Jacob, W. C.
Edmundson, W. C., see Stevenson, F. J.
Frutchey, C. W. What are the real values and facts of seed potato certification. 245-249.
Fults, J. L., L. A. Schaal, W. Landblom, and M. G. Payne. Stabilization and intensification of red skin color in red McClure potatoes by use of the sodium salt of 2-4 dichlorophenoxyacetic acid. 377-395.
Gardner, R., see Kunkel, R.
Gould, C. J. and T. E. Randall. Potato tuber disinfection tests in western Washington. 249-256.
Gowen, M., see Terman, G. L.
Granovsky, A. A., see Peterson, A. G.
Greenwood, M. L., see Harvey, M. H.
Hardenburg, E. V. Effects of water submersion of seed value of potato tubers. 142-150.
Harvey, M. H. The effectiveness of certain antidotes in counteracting the off-flavor in potatoes grown on soil treated with benzene hexachloride. 182-188.
Haslett, E., see Patterson, H. L.
Hastings, R. C. How much certified seed is needed and the problem of meeting this demand. 47-52.
Hooker, W. J. and G. C. Kent. Sulfur and certain soil amendments of potato scab control in the peat soils of Northern Iowa. 345-365.
Houghland, G. V. C. An improved technique for growing potatoes in solution cultures. 257-262.
Hunter, A. S. and E. A. Talley. Acid hydrolysis of potatoes under pressure. 425-438.
Jacob, W. C. and L. A. Dean. The utilization of phosphorus by two potato varieties on Long Island. 439-445.
Juul, Fleming. Studies on blackening of potatoes after cooking (book review) 32-35.
Kelley, R. A., see Adams, J. B.
Kent, G. C., see Hooker, W. J.
Knight, K. G., see Paul, P.
Koehnke, M. Report of seed potato certification and regulation in the U.S.A. and Canada. 236-237.
Kunkel, R. and R. Gardner and A. M. Binkley. Results of fertilizer trials on potatoes in the San Luis Valley. 309-318.
Landblom, N., see Fults, J. L.
Larson, R. H. The spread of ringspot virus X by cutting knife. 53-54.
Lombard, P. M. The effect of a mild strain of latent mosaic Virus X on yield of some of the new potato varieties in Maine. 445-449.
Lorenz, O. A. Air and soil temperatures in potato fields, Kern County, California, during spring and early summer. 396-407.
Lutz, J. M., see Nylund, R. E.

Maclinn, W. A., J. P. Reed, and J. C. Campbell. Flavor of potatoes influenced by organic insecticides. 207-213.
Mac Gillivray, J. H. Effect of irrigation on the production of white potatoes. 10-23.
Marshall, E. R., and O. Smith. Effect of field and storage applications of sprout inhibitors on potato tubers. 133-141.
Marth, P. C., and E. S. Schultz. Effect of growth regulators on sprouting of stored table stock potatoes and on waste piles for control of diseases. 23-32.
Muncie, J. A. Donald Reddick cited. 161.
Nylund, R. E., and J. M. Lutz. Separation of hollow-heart potato tubers by means of size, grading, specific gravity, and X-ray examinations. 214-222.
Parks, N. M. Procedure in introduction of new varieties of potatoes in Canada. 55-58.
Patterson, H. L., and E. Haslett. Costs of potato production in central and western Ontario, Canada. 285-286.
Paul, P., B. I. Coles, and K. G. Knight. Factors contributing to the utility as food of five grades of Michigan potatoes. 189-198.
Payne, M. G., see Fults, J. L.
Peterson, A. G. and A. A. Granovsky. Feeding effects of *Empoasca fabae* on a resistant and susceptible variety of potato. 366-371.
———. Insecticide experiments on potatoes in Minnesota during 1949. 319-326.
Peterson, L. C., see Reddick, D.
Peppin, S. G. Seed potato certification in Canada. 93-96.
Randall, T. E., see Gould, G. J.
Rawlins, W. A., and A. C. Davis. Recent progress in the control of wireworms on potatoes. 151-158.
———. Potato production by E. V. Hardenburg. Review. 199-200.
Reddick, D., and L. C. Peterson. Additional blight-resistant varieties. 1-10.
Reed, J. P., see Maclinn, W. A.
Rich, A. E. The effect of various defoliants on potato vines and tubers in Washington. 87-92.
Ross, H., and M. L. Baerecke. Selection for resistance to Mosaic virus (diseases) in wild species and in hybrids of wild species of potatoes. 275-284.
———, see Rudorf, W.
Rudorf, W., P. Schaper, H. Ross, M. L. Baerecke, and M. Torka. The breeding of resistant varieties of potatoes. 222-235.
———, Methods and results of breeding resistant strains of potatoes. 332-339.
Schaal, L. A., see Fults, J. L.
Schaper, P., see Rudorf, W.
Schultz, E. S., see Marth, P. C.
Smith, O., see Marshall, E. R.
Sparks, W. C. Injury studies in Idaho grown russet Burbank potatoes. Part I. Shipping and handling. 287-303.
Stevenson, F. J., and W. C. Edmundson. Storage of potato seeds. :408-411.
Talley, E. A., see Hunter, A. S.
Terman, G. L., M. Goven, and C. E. Cunningham. Effect of storage temperature and size on French fry quality, shrinkage and specific gravity of Maine potatoes. 417-424.
Torka, M. Breeding potatoes with resistance to the Colorado beetle. 263-271.
———, see Rudorf, W.
Turner, N., see Harvey, M. H.
Werner, H. O. Peeling economy as affected or influenced by size and grade of Triumph potatoes. 97-113.

AMERICAN POTATO JOURNAL

Subject Index

Vol. 27 Nos. 1-12

American Potato Yearbook announced. 237.
Antidotes — see Benzene hexachloride, also Off-flavor.
Aphids
potato control studies, 1946-1947, at Woodstock, N. B., Canada. 175-182.

Benzene hexachloride, see Flavor
antidotes to counteract off-flavor in potatoes grown on soil treated with, 182-188.
Blackening (of potatoes after cooking),
studies of, 32-35.
Blight
breeding for resistance to, see Breeding
resistant varieties, 1-10.
Bordeaux mixture
copper sulphate-lime ratios in, 327-331.
Breeding
disease resistant strains of potatoes, 332-339.
of blight resistant varieties of potatoes, 222-235.
potatoes with resistance to the Colorado beetle, 263-271.
use of virus resistant wild species, 275-284.
Certification, Seed, see Seed Potato Certification.
Certified seed, see Seed, Certified.
Colorado beetle
resistance to, see Breeding
Copper sulphate-lime ratios (in Bordeaux mixture) see Bordeaux mixture 327-331.
Costs of potato production, see Production, costs of,
Cultures (solution)
improved technique for growing potatoes in, 257-263.
Defoliants
effect on vines and tubers, 87-92.
Diseases, see Specific diseases *e.g.* Mosaic virus
Disinfection, Potato tuber
tests in western Washington, 249-256.
Economy, peeling, see Peeling economy
Empoasca fabae, see Leafhopper
Fertilizer
in San Luis Valley, 309-318.
Flavor,
as influenced by organic insecticides, 207-213.
Food, utility of potatoes as,
factors contributing to the, 189-192.
French fry quality (of Maine potatoes)
Growing potatoes (in solution cultures), see Cultures, (solution),
Growth regulators
effect of, on stored table stock and on disease control in waste piles, 23-32. see also Sprout Inhibitors.
Hollow heart potato tubers,
separation of, 214-222.
Hydrolysis, Acid, 425-438.
Injury studies
on Idaho grown Russet Burbank potatoes, shipping and handling, 287-303.
Insecticide,
experiments on potatoes in Minnesota, 319-326.
Irrigation, effect of
on the production of white potatoes, 10-23.
Latent Mosaic Virus X, see Mosaic Virus X, latent, 445-449.
Leafhoppers,
feeding effects of, 366-371.
Maine potatoes, see French fry quality, 417-424.
Minutes
of annual meeting, December 8, 1949, 37-41.
Mosaic Virus, see Breeding
Mosaic, Virus X, latent
effect of a mild strain of, on yield of new potato varieties in Maine, 445-449.
Off-flavor, antidotes to counteract, 182-188
Organic insecticides, see Flavor
Peeling economy, 97-113

Phosphorus, Utilization of on Long Island. 439-445.
Potato Association of America
program of the annual meeting. 413-415.
Potato conference, Western Regional Research Laboratory, 1949.
summary of papers. 59-85; 115-131.
Potato scab control
with sulfur in peat soils of northern Iowa. 343-365.
Potato seeds
storage of. 408-411.
Production,
costs of, in central and western Ontario, Canada. 285-287.
Potato Production (book review) 199-200
Program, see Potato Association of America
Red McClure potatoes
red skin color in, as affected by 2-4 dichlorophenoxyacetic acid. 377-395.
Red skin color, see Red McClure potatoes.
Reddick, Donald
cited. 161
Resistance, see Breeding
Resistant strains, see Breeding
Ringspot, Virus X
Spread of, by cutting knife, 53-54.
Sale, factors affecting, see Food, utility of potatoes
San Luis Valley
results of fertilizer trials, see Fertilizer
Scab,
see Potato scab control
Schultz, Eugene S.
honored 159-160.
Seed, Certified
demand. 47-52.
Seed Potato Certification
values of 245-249
in Canada. 93-96.
in U.S.A. and Canada. 236-237.
Seed submersion, see water submersion
Sprout inhibitors,
field and storage applications of, 133-141. see also Growth regulators.
Sprouting, see Growth regulators
Storage, see Potato seeds
Submersion, see water submersion
Sulfur, see Potato scab control
Temperature,
air and soil, in potato fields, 396-407.
Trials, see Fertilizer
Triumph variety
peeling economy of, as affected by size and grade. 97-113.
Tubers
effect of defoliants on, see Defoliants
effect of water submersion on, see Water submersion.
Varieties
introduction of, 55-58
Water submersion
effect of, on seed value of potato tubers. 142-150.
Western Regional Research Laboratory
summary of papers presented. 59-85; 115-131.
Wireworms
control of, 151-158
Woodstock, N. B., Canada
aphid control studies, 1946-1949, see Aphids.

ERRATUM

In the article entitled, "Results of Fertilizer Trials on Potatoes in the San Luis Valley" published in the September issue of the American Potato Journal, the data belonging to Figs. 1 and 3 have been reversed, so that color measurements are over the title for yield and yield data over the title for color.

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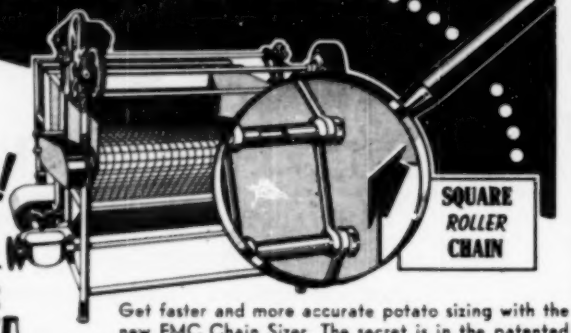

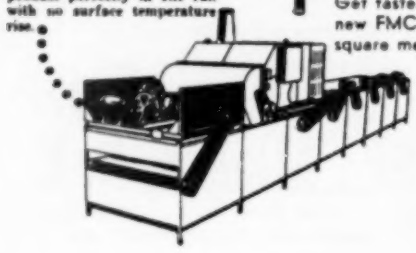

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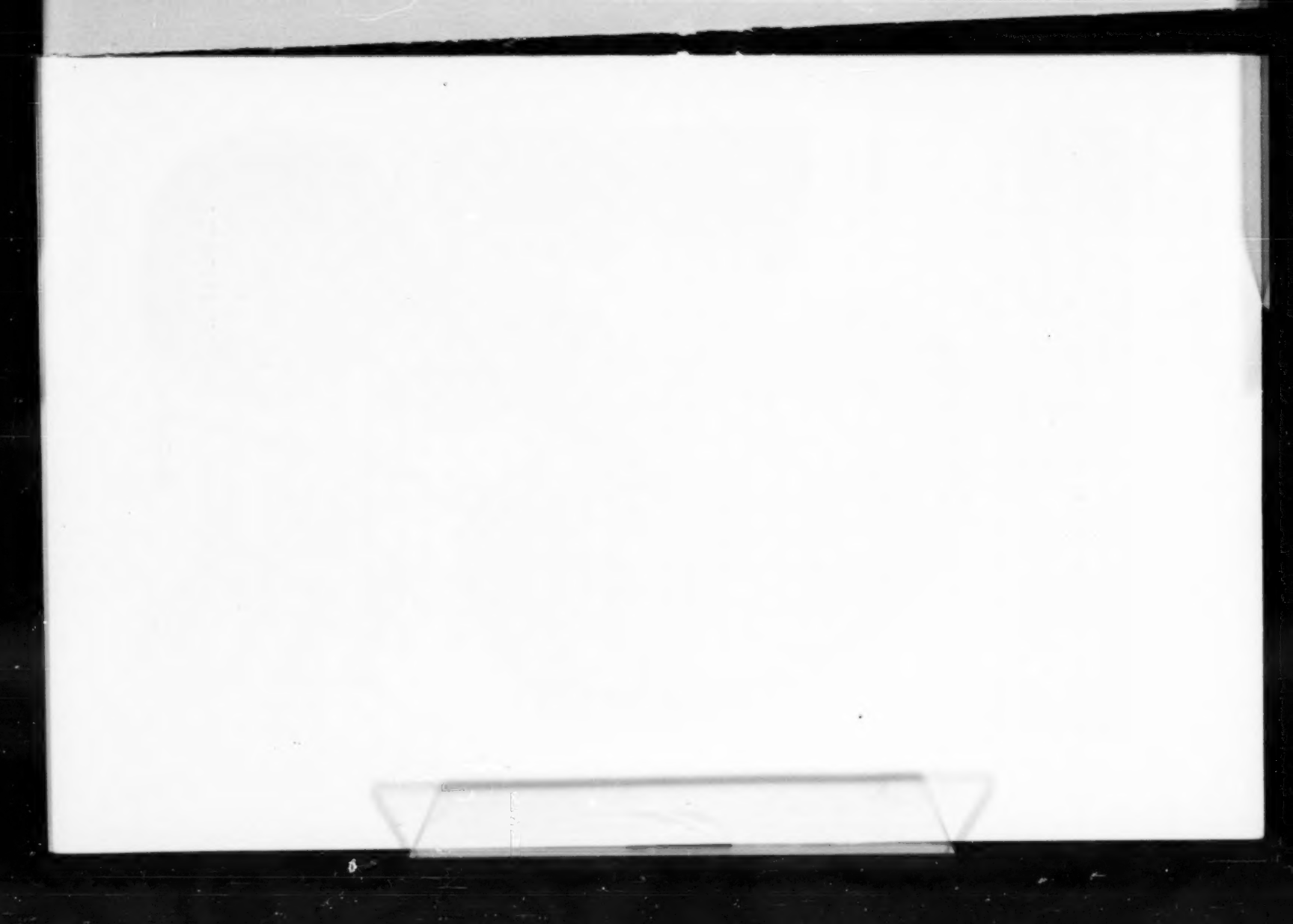

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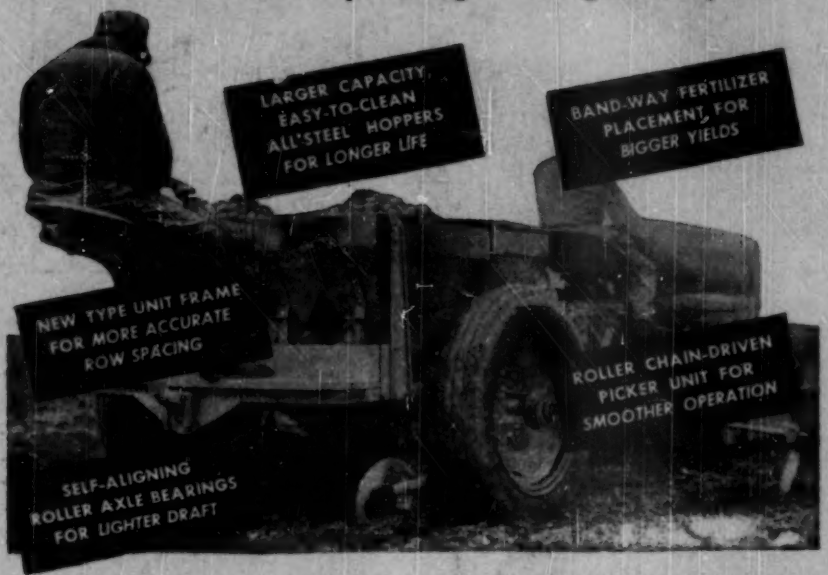
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